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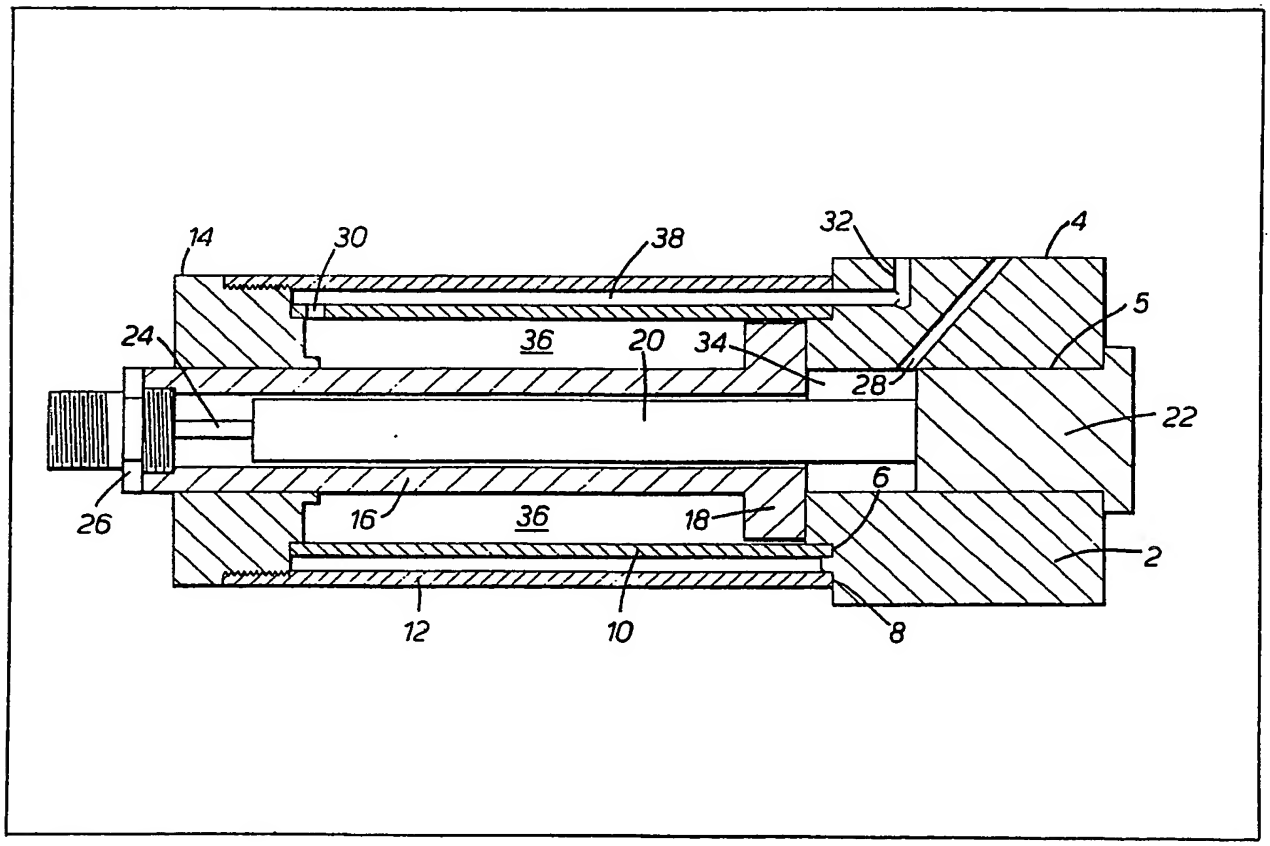
(54) **Linear actuator with piston position transducer**

(57) The actuator, hydraulic or pneumatic, comprises a body composed of concentric tubes 10, 12 which are spaced to define a passage 38 through which fluid is fed from a valve block at one end of the actuator to the end of the actuator remote from the valve block to obviate the need for external piping. The piston rod 16 of the actuator also comprises a tube and receives a position-sensing transducer 20, 24, e.g. having a potentiometer, which is exposed by fluid in one chamber defined by the piston 18 and the body.



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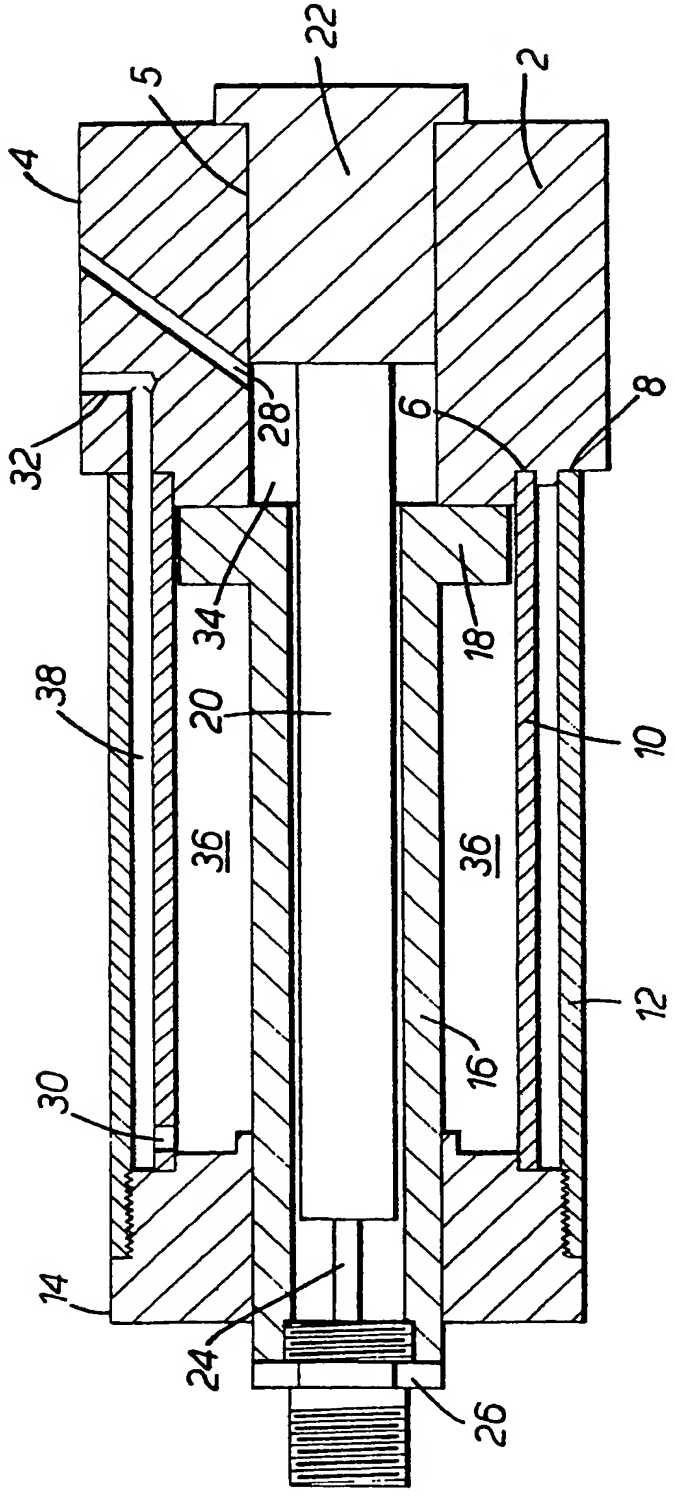

SPECIFICATION
Linear actuators

The present invention relates to linear actuators and more particularly to linear hydraulic actuators, for example for use in servo control systems of robotic systems.

Linear hydraulic actuators for use in servo or robotic systems conventionally comprise a hydraulic cylinder associated with a transducer for sensing the position of a piston rod of the cylinder relative to the body of the cylinder and producing position signals which are used in the control system for hydraulic fluid fed to the cylinder to retract or extend the piston rod to a predetermined position. In one previously proposed form of linear actuator, the transducer is located externally of the hydraulic cylinder and tends to be vunerable to damage. In addition, external piping and external connections are used to feed hydraulic fluid to the remote end of the cylinder and there is a risk of leakage occuring at this point. In another previously proposed form of linear actuator, the transducer is located within a hollow piston rod of the cylinder and out of contact with the hydraulic fluid. With this design, the piston rod extends from both ends of the cylinder which necessitates additional bearings and seals for the piston rod. The hydraulic fluid is fed to the chambers of the cylinder either through relatively complex drillings formed in the body of the cylinder which is machined from a solid block and therefore expensive to produce, or by means of external piping with the consequent risk of leaks occurring.

According to the present invention, there is provided a fluid-operated linear actuator comprising a piston movable within a tube along the axis thereof, a piston rod rigid with the piston and extending through an end of the tube, said piston rod being hollow and a transducer being contained within the hollow interior of the piston rod, said transducer comprising two relatively movable parts secured respectively to the piston rod and the cylinder so that it is responsive to the position of the piston relative to the cylinder, and said transducer being exposed to fluid within the tube on one side of the piston.

Further according to the present invention, there is provided a fluid-operated linear actuator comprising a body which includes an outer tube, an inner tube located within and spaced from said outer tube to define a passage therebetween, a piston within and slidable along said inner tube, a piston rod rigid with said piston and extending to the exterior of the inner tube, the piston dividing a space within the body into two fluid chambers, one chamber having a fluid flow connection to the exterior of the body via said passage, and a transducer comprising two relatively movable parts connected respectively to the piston rod and the body to produce a signal indicative of the position of the piston relative to the body, the transducer being located within one of said chambers and exposed to fluid therein.

Again, the present invention provides a fluid-operated actuator comprising a body which includes an outer tube, an inner tube located within and spaced from said outer tube to define a passage therebetween, a piston within and slidable along said inner tube, a tubular piston rod rigid with the piston and extending to the exterior of the body, the piston dividing a space within the body with two fluid chambers, one of which includes the hollow interior of the piston rod, a transducer located within the interior of the piston rod and exposed to fluid therein, said transducer comprising two relatively movable parts connected respectively to the body and to the piston rod to produce a signal indicative of the position of the piston relative to the body, said chambers having fluid connections to the exterior of the body, one of which includes said passage.

The novel features of the invention will be apparent from the following description given by way of example only, with reference to the accompanying diagrammatic drawings, the sole Figure of which is a longitudinal section through a linear actuator in accordance with a preferred embodiment of the present invention.

As shown in the accompanying drawing, the actuator comprises a block 2 which carries on a plane outer face 4 a body (not shown) containing hydraulic valves and a connection leading to a source of hydraulic fluid under pressure. The block 2 is provided with a central axially directed bore 5, and with inner and outer concentric annular grooves 6 and 8 formed on one end face of the block 2 co-axially with the bore 5.

The grooves 6 and 8 define seats for the ends of inner and outer tubes 10 and 12 which extend axially of the actuator. At their ends remote from the block 2, the tubes 10 and 12 are secured to a stepped end face of an annular block 14. The outer tube 12 is secured to the blocks 2 and 14 in a manner which renders the connection leak proof, and in the embodiment shown, the outer tube 12 is secured to the block 2 by welding or brazing and to the block 14 by a screw thread which is sealed to prevent leakage of hydraulic fluid. The inner tube 10 may be press fit with the two blocks 2 and 14 with O-ring seals (not shown) being provided between the inner tube 10 and the two blocks. As will be apparent, other forms of sealing connection between the two tubes and the two blocks can be used.

The piston and piston rod assembly of the actuator is defined by a third tube 16 extending to the exterior of the actuator body through the bore in the second block 14 and carrying at its inner or rear end a collar 18 which forms the piston of the assembly and which is slidable within the inner tube 10. Suitable sealing means (not shown) are provided in the bore of the block 14 to provide a seal between the bore of the block and the outer surface of the piston rod tube 16, and also sealing means (not shown) are provided between the piston 18 and the tube 6.

A position-sensing transducer is mounted within the interior of the piston rod tube. In the

embodiment shown, the transducer comprises a cylinder 20 which extends forwardly into the interior of the piston rod tube from a plug 22 which closes and seals the end of the bore 5 in the block 2, the cylinder 20 of the transducer thereby being held fast with respect to the body of the actuator. A piston rod 24 of the transducer extends forwardly through the forward end of the cylinder 20 to be connected to an end assembly 26 which closes and seals the forward end of the piston rod tube 16. The transducer cylinder 20 contains a potentiometer, the output voltage of which is dependent upon the distance by which the piston rod 24 of the transducer extends from the cylinder 20 of the transducer. As will be apparent, since the piston rod 24 of the transducer is connected via the end assembly 26 to the piston rod tube 16 of the actuator and will therefore move with the piston rod tube 16, the output voltage from the potentiometer will be representative of the position of the piston rod tube 16. The output from the transducer is fed via leads (not shown) extending from the plug 22 in the block 2 to control circuitry for the actuator, the plug 22 including means for sealing the leads.

The piston rod tube 16 of the actuator is advanced by hydraulic fluid fed through a passage 28 in the block 2 to the chamber 34 formed in the interior of the actuator body behind the piston. This chamber is defined between the rear surface of the piston 18 and the plug 22 which closes the bore 5 in the block 2. It will be seen from the drawing that the interior of the piston rod tube 16 opens into this chamber and therefore the interior of the piston rod tube 16 is also filled with hydraulic fluid. The piston rod rube 16 is retracted by hydraulic fluid fed into a chamber 36 in front of the piston 18 and defined between the piston 18 and the block 14 and between the inner tube 10 and the piston rod tube 16. To permit hydraulic fluid to pass to and from this forward chamber an aperture 30 is formed at the forward end of the inner tube 10 to communicate the forward chamber with the annular space 38 formed between the inner and outer tubes 10 and 12.

At its rear end, this annular space communicates with a passage 32 formed in the block 2 and which opens onto the face 4 to be connected to the valve block. The passage 28 likewise opens onto the face 4 to be connected to the valve block.

It will be apparent that the annular space 38 formed between the inner and outer tubes 10, 12 thus forms an annular passage extending between the valve body carried at the rear of the actuator, and the front end of the forward chamber of the actuator. In this manner, external piping which would otherwise be required to feed hydraulic fluid from the valve body to the forward chamber 36 is obviated. This passage is confined totally within the body of the actuator and sealing problems do not arise because a seal can readily be obtained between the outer tube 12 and the two blocks 2 and 14. Although it is necessary to provide the two passages 28, 32 in the block 2, these passages can nevertheless be produced by simple drillings.

As discussed earlier, the interior of the piston rod tube 16 communicates with rear chamber 34 of the actuator and is filled with hydraulic fluid and therefore the transducer is immersed in the hydraulic fluid. To enable the transducer to withstand high pressures within the actuator, (and which in some applications may reach 3,000 psi) the cylinder 20 of the transducer is also filled with hydraulic fluid. Vent holes provide communication between the fluid within the interior of the transducer cylinder 20 and the fluid external of the transducer cylinder 20 to provide pressure equalisation between the two bodies of fluid.

In modified embodiments, other forms of position-sensing transducers may be used to provide an output representative of the position of the piston rod tube of the actuator.

The inner and outer tubes used in the construction of the actuator body and the tube used to form the piston rod of the actuator permit a significant part of the actuator to be formed from preformed tubing which avoids expensive machining operations and also avoids the necessity for external piping to carry hydraulic fluid to and from the end of the actuator body remote from the valve block. The mounting of the transducer inside the piston rod and, in effect, within one of the two hydraulic chambers leads to a compact form of construction.

The invention is also applicable to pneumatic actuators.

CLAIMS

1. A fluid-operated linear actuator comprising a piston movable within a tube along the axis thereof, a piston rod rigid with the piston and extending through an end of the tube, said piston rod being hollow and a transducer being contained within the hollow interior of the piston rod, said transducer comprising two relatively movable parts secured respectively to the piston rod and the cylinder so that it is responsive to the position of the piston relative to the cylinder, and said transducer being exposed to fluid within the tube on one side of the piston.

2. A fluid-operated linear actuator comprising a body which includes an outer tube, an inner tube located within and spaced from said outer tube to define a passage therebetween, a piston within and slidable along said inner tube, a piston rod rigid with said piston and extending to the exterior of the inner tube, the piston dividing a space within the body into two fluid chambers, one chamber having a fluid flow connection to the exterior of the body via said passage, and a transducer comprising two relatively movable parts connected respectively to the piston rod and the body to produce a signal indicative of the position of the piston relative to the body, the transducer being located within one of said chambers and exposed to fluid therein.

3. A fluid-operated actuator comprising a body which includes an outer tube, an inner tube

located within and spaced from said outer tube to define a passage therebetween, a piston within and slidable along said inner tube, a tubular piston rod rigid with the piston and extending to the exterior of the body, the piston dividing a space within the body with two fluid chambers, one of which includes the hollow interior of the piston rod, a transducer located within the interior of the piston rod and exposed to fluid therein, said transducer comprising two relatively movable parts connected respectively to the body and to the piston rod to produce a signal indicative of the position of the piston relative to the body, said chambers having fluid connections to the exterior of the body, one of which includes said passage.

4. An actuator according to claim 2 or claim 3 wherein said body further comprises two spaced apart blocks which are in sealed engagement with the opposite ends of said outer and inner tubes, one said block having a passage therein through which fluid can be supplied to the passage defined between said tubes.

5. An actuator according to claim 4 wherein said inner tube contains an aperture in a portion thereof which is not swept by said piston.

6. An actuator according to claim 4 or claim 5 wherein a first part of the transducer is fixed to a member secured in said one block, and a second part of the transducer which is movable relative to said first part is fixed to a member secured to said piston rod.

7. A fluid-operated linear actuator substantially as herein described with reference to the accompanying drawings.

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